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ABSTRACT

This project was created to help music students in their development of part-writing and harmonization skills, requirements for college-level music study. It was developed and programmed by members of the Instructional Technology Center and Department of Music at the University of Delaware. The software developed during this project provides students with a robust environment in which to develop skills in the areas of chorale-style part-writing. Exercises dealing with soprano harmonization, bass harmonization, inner-voice completion, figured-bass realization, and harmonic analysis are anticipated. Using innovative techniques, students are able to enter notation symbols using either direct manipulation of notational symbols or via a graphical keyboard. Multiple layers of feedback are available to the student to encourage self-discovery of errors made. When a given skill has been mastered, the student will be branched to the next area of instruction. Appendices include attitudinal questionnaire and results; music pre- and post-tests; seventh chords/secondary dominants test and instructions; and comments to FIPSE. (SWC)

COMPUTER LESSONS FOR WRITTEN HARMONY

Final Project Report

(FIPSE Project Number: P116B11226-93)

September 29, 1995

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University of Delaware
Newark, DE 19716

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Year 1	$ 58,087	
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Year 4	$ 0	(no cost extension)
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TABLE OF CONTENTS

PROJECT SUMMARY

The project "Computer Lessons for Written Harmony" was created to help music students in their development of part-writing and harmonization skills, requirements for college-level music study. It was developed and programmed by members of the Instructional Technology Center and Department of Music at the University of Delaware, and tested with music students there and elsewhere. Continued testing and dissemination to other locations is planned.

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EXECUTIVE SUMMARY

A. Project Overview

The project "Computer Lessons for Written Harmony" was created to help music students in their development of part-writing and harmonization skills. These skills are an important part of the development of musicians and present difficulties in teaching and learning which are well addressed by computer-based instruction.

B. Purpose

Learning part-writing and harmonization takes time and a great deal of drill-and-practice with in-depth feedback from the instructor. In the typical class, the teacher assigns exercises either in class or for homework. Then the teacher must grade each homework assignment in detail. Because of the large number of students in a class and because of the great amount of detailed commentary required for each exercise for each student, the teacher cannot give the number of exercises or the amount of feedback required for the optimum learning experience. What is required for mastery of the music theory skills is 1) a huge pool of exercises, 2) a way to determine student mastery, 3) a way to determine each student's unique problem areas, 4) specific feedback and exercises for the student at each point of difficulty, and 5) a way to assess whether the instructional approach is working.

This project developed software that provides students with a robust environment in which to develop skills in the areas of chorale-style part-writing. Exercises dealing with soprano harmonization, bass harmonization, inner-voice completion, figured-bass realization, and harmonic analysis will be available. Using innovative techniques, students are able to enter notation symbols using either direct manipulation of notational symbol or via a graphical keyboard. Multiple layers of feedback are available to the student to encourage self-discovery of errors made. When a given skill area has been mastered, the student will be branched to the next area of instruction.

C. Background and Origins

For over twenty years, the University of Delaware has made a major commitment to computer-based education. Through the Instructional Technology Center (ITC), the University has developed instructional lessons on a variety of microcomputers, as well as on the Control Data PLATO system and Digital's VAX computer. Over the years, 111 faculty from thirty-five departments have worked with ITC's professional programmers and instructional designers to create hundreds of hours of software programs for students on campus and throughout the world. ITC relies on a team approach to courseware development, drawing on the combined expertise of faculty members, instructional designers, and programmers. This cooperation has resulted in over four hundred instructional programs, including intelligent tutoring systems, interactive videodiscs, CAD/CAM tools, simulations, drills, and tutorials. Members of the campus community may go to any of more than thirty campus computing sites that provide access to Apple II, Apple Macintosh, IBM PC and PS–2, Sun, and centralized mainframe computing resources.

The Department of Music has long been a leader in the area of computer-based instruction. In 1975, Professor Fred Hofstetter developed the GUIDO Ear-Training System on the PLATO mainframe. This very successful software package was the first in a large number of innovative music projects at the University over the years utilizing state-of-the-art technology culminating in the "Sight-Singing," "Written Harmony", and "Interactive Jazz Theory" projects funded by the Fund for the Improvement of Post-Secondary Education (FIPSE) of the Department of Education. The Department of Music of music offers the Bachelor of Arts and Bachelor of Music Degrees in performance, music education, and music theory/composition to more than 100 undergraduate music majors. Recently, the Department expanded its degree offerings to include graduate study through a Masters of Music in Performance and Music Education. Non-majors have the opportunity to concentrate on a lesser level in music through minors in Applied Music, Musical Studies, and Jazz Studies. The Department also provides the opportunity for musical study to hundreds of non-majors every year through a large number of music courses. All music majors in the Department are required to take at least two years of harmony and ear-training as part of their degree programs. Students enrolled in the Applied and Musical Studies minors are required to take the first semester courses in harmony and ear-training. The GUIDO Ear-Training and Written Harmony Programs already in place provide needed drill-and-practice in aural and written skills to all majors and Applied and Musical Studies minors.

D. Project Description

The principal feature of the project was the development of software which provides written harmony training for students. Four principal areas of concern influenced the design of these lessons: efficient and intuitive user interface, multi-layer feedback presentation system, customization of the materials by instructors, and easy collection of student data.

E. Evaluation/Project Results

Data are being collected to determine both improvements in student written harmony skills and changes in attitudes toward written harmony. To assess improvement skill improvement, a pre-test and post-test were administered to a sample of students at the University of Delaware and Indiana University. Control and experimental groups were established at the sites. No statistically significant differences in skill improvement was detected between the groups.

To assess students attitudes toward the software and its subject area, we administered an affective questionnaire at the end of the semester. These data have been collected over the past four years and will continue to be collected under a time-series analysis model.

F. Summary and Conclusions

We have made great progress in resolving the problems that at the outset we thought would be most formidable. While technical problems with software and hardware have greatly impeded the progress of this project, great strides have been made in overcoming the central theoretical issues that once seemed formidable. We intend to continue work on the project long after the grant period is over and to develop the software into a commercial product.

REPORT

A. Project Overview

The project "Computer Lessons for Written Harmony" was devised in order to address problems involved in part-writing, harmonization, and analysis of pieces utilizing four-part chorale style. The study of four-part chorale style forms the skill basis for the study of more advanced musical concepts such as composing, arranging, and analysis. In many ways it is like a board game in which pieces (musical notes) can be moved about the board (musical staff) within the constraints of an historically evolved rule set. The implications of a decision made early in a progression (sequence of chords) may not become obvious until many chords later when an impossible situation is reached. The rule-base is large and varied with rules governing such facets as chord spelling, chord doubling, chord spacing, voice range, and connection procedures. Learning to write in this idiom takes extensive practice and careful, on-the-spot, in-depth feedback. Such guidance requires a huge pool of exercises, a way to determine student mastery, a way to determine each student's unique problem areas, and specific feedback and exercises for the student at each point of difficulty.

B. Purpose

This project had as its purpose the development of software for teaching music students the cognitive skills needed to correctly write and analyze musical exercises in four-part harmony. Drawing upon techniques from the field of artificial intelligence, the software constantly assesses student learning, determines mastery levels as they change, pinpoints faulty student approaches, provides exact, customized feedback for remediation, and moves the student quickly to the most appropriate unmastered level. A set of instructor options allows teachers to adapt the curriculum to local needs. The software can be easily disseminated to students internationally through existing channels.

Specifically, it is the purpose of the software to help the student achieve improved abilities in the areas of harmonization, chord spelling, recognition and labeling, visual realization of figured basses, and the ability to correlate visual symbols (musical notation) with aural perception and recognition. Other goals of the project include the acquisition of new insights into the process by which students come to understand the harmonic process through the examination of user data collected by the software. These insights could change the way music theory is

taught with a shift away from repetitive activities and a shift toward higher-order musical activities

C. Background and Origins

For approximately the last twenty years, the University of Delaware (UD) has been committed to using technology, in particular computer-based technology, in the instruction of music students. In 1977, through a University of Delaware Center for Teaching Effectiveness Grant, a very effective computer-based instruction package entitled the GUIDO Music Theory System was created for the PLATO mainframe. The system consisted of a series of drill-and-practice lessons in a variety of areas. The lessons were intended to be a secondary activity in support of the work done in the classroom. Students received information from the teacher and the textbook. Then the students went to the computer lab where they worked on the drill-and-practice lessons in an attempt to gain accuracy and speed at the skills involved. The lessons were all table-driven, which meant that they could be customized by the instructor and were all competency-based, which meant that the student had to achieve a certain competency on each unit in each lesson before going on to the next. The criteria for competency involved accuracy as well as response time. Through the table for each lesson, the instructor could control the level of accuracy and response time required to achieve competency. In 198x, the University of Delaware (through its Instructional Technology Center) funded the conversion of these lessons for use on the IBM-PC and compatibles.

Most of the GUIDO Music Theory System lessons have been quite excellent and work well for the drill-and-practice of music theory skills. The Part-Writing Lesson in that package, however, has limitations which make it less than satisfactory: (1) The lesson involves a two-chord context. Students are given a first chord and are then asked to create a second chord. After the student makes an attempt at that task, s/he receives feedback regarding mistakes in doubling and part-writing and then has a chance to correct the errors. Although a student can learn a great deal about the principles of part-writing from the two-chord context, real music and exercises found on tests in the harmony courses involve a multi-chord context which makes part-writing much more challenging. Thus the two-chord situation does not prepare the student for real music or the testing situation in the harmony courses. (2) The lesson does not allow for harmonization. In harmonization, a student is given one of the voices and is then asked to create the other three voices and identify chords. It is a very important skill but is not covered in the Part-Writing Lesson or any other lesson in the GUIDO Music Theory System. (3) The lesson does not provide enough feedback. When the student makes an error in the second chord, s/he is given some information about the error made and the voice that is applicable but the feedback is very general in nature and is not always very helpful. (4) The lesson does not provide for

branching. When the student makes the same error repeatedly, the lesson should be intelligent enough to branch him/her to a remedial lesson that will address the type of error being made. Instead, in the Part-Writing Lesson, the student may continue to flounder until finally giving up.

The Part-Writing Lesson does have features that are very positive and were incorporated into the Written Harmony Lessons. The Part-Writing Lesson and others in the GUIDO Music Theory System are table-driven and competency-based. The table-driven capability allows individual instructors control over the content and other variables for each of the units in every lesson meaning that they can tailor the unit design for their own courses, allowing for differences in course content and in pedagogical philosophy. In addition to content, one of the major variables that can be controlled in the table-driven design is competency. Control over this variable enables an instructor to insure that a student achieves mastery of the material in a given unit. The instructor can set the number of questions which must be answered correctly in one unit before begin allowed to proceed to the next unit. The instructor can also decide to require the student to answer each question within a maximum amount of time. As an example, the instructor can set the competency for a unit to require that a student. answer nine out of ten questions correctly with a maximum time of two minutes.

D. Project Description

Deliverables

The deliverables for this project divided into two categories. These categories were design specification documents and software. Each category is discussed below.

Specification Documents

The specification documents produced by this project were of three basic types. Documents covering the pedagogical, visual, and technical aspects of the project were produced. These documents served as the blueprints for the work done by this project and will serve as the basis for future expansions to the work of this project.

Software

The project produced three pieces of software each of which runs on both the Macintosh and Windows platforms. The three pieces of software produced were the "Instructor Editor," the "Student Roster", and "Written Harmony."

Instructor Editor

The "Instructor Editor" software allows instructors to customize the instructional materials delivered to their students. Instructors have control over the following parameters in each unit of instructions that they create.

Title	Descriptive title for the unit
Competency Standards	Method to determine student competency
Question Length	Number of chords in the exercises
Question Types	Type(s) of questions to be presented
Answer Timing	Maximum for a user response (if desired)
Keys	Key signatures to be used in the exercises
Pitch Input Method	Method of pitch input to be used
Harmonic Label Type	Types of harmonic labels to be used
Harmonic Content	Chords to be included in the exercises

Roster

The "Roster" software allows instructors to enroll students for access to the instructional courses that they create with the "Instructor Editor."

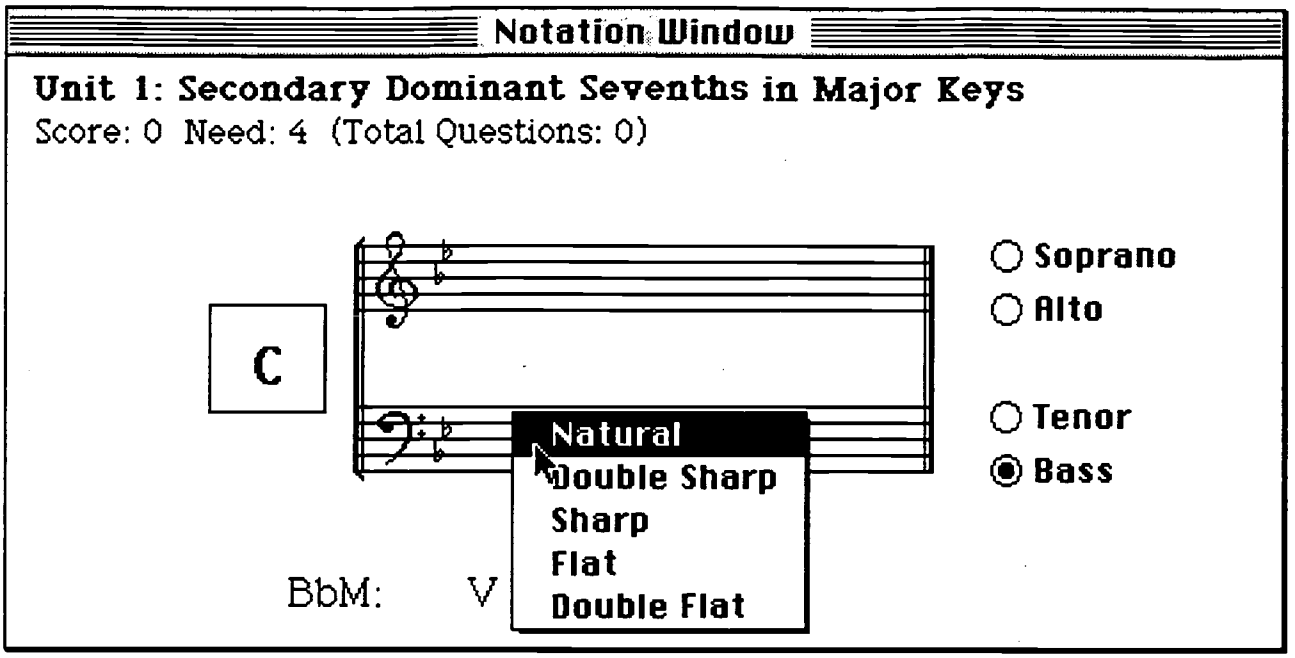
Written Harmony

The "Written Harmony" software is the module used by students to work with the instructional materials developed by their instructor. This software allows students to select from available instructional materials, enter their solutions to exercises generated, and to receive feedback on their work.

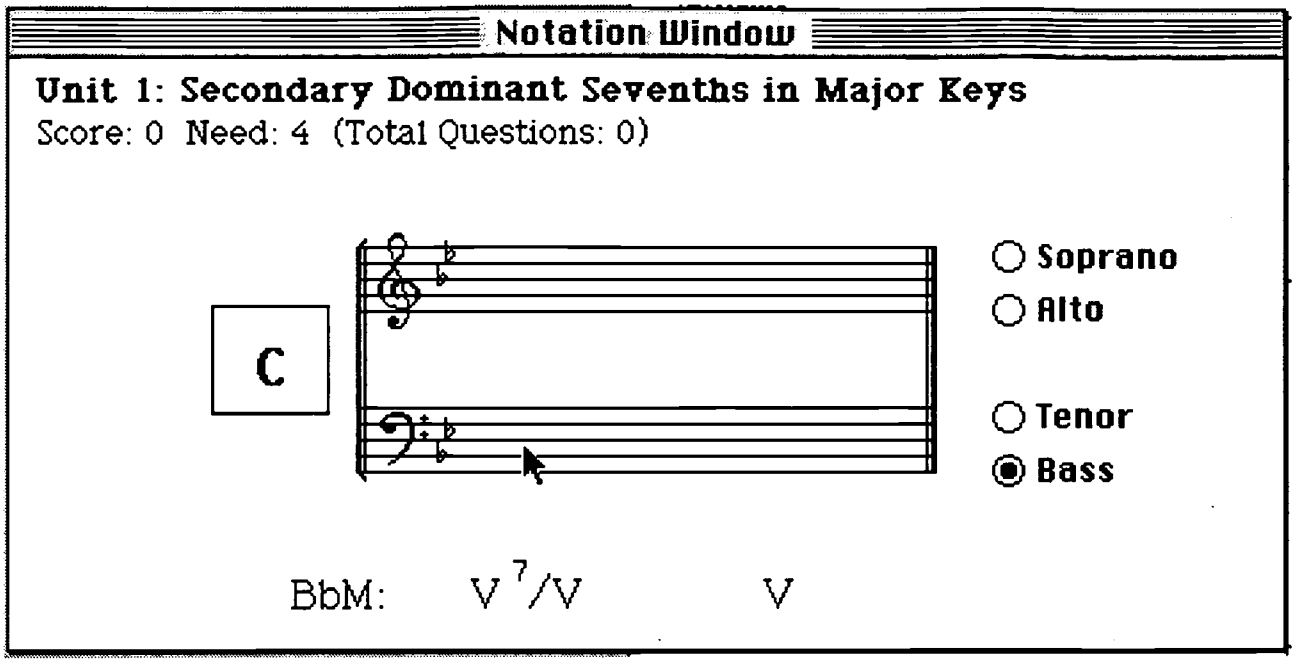
Accomplishments

Notation Input

One of the most important user interface elements in an application dealing with musical notation is the way in which users interact with the musical symbols in the creation and editing of music notation. This interaction is significant because of the frequency of its use. Users spend the majority of their time entering musical symbols or editing existing symbols in response to feedback. This project developed a novel procedure for notational entry. A single click of the mouse upon a musical staff selects the basic pitch class (A, B, C, etc.) and the octave. This click also brings up a pop-up menu from which users can select a chromatic modifier (if needed) to be added to the current note. An example of this pop-up menu is shown in the figure below.



This project also solved a problem frequently encountered with existing "click on the staff" notation input schemas. With many existing applications, users do not know exactly which staff position the mouse cursor in over. Hence, they do not know which musical pitch will be selected if they click the mouse button at the current location. As show in the figure below, this problem is addressed in this software by providing continuous feedback in the box to the left of the grand staff. The contents of this box always let the user know which pitch class will be selected if they click now. When the mouse cursor is not over the staff portion of the display, the box is empty indicating that the cursor is not currently in a position to select a note given the range of the current voice.



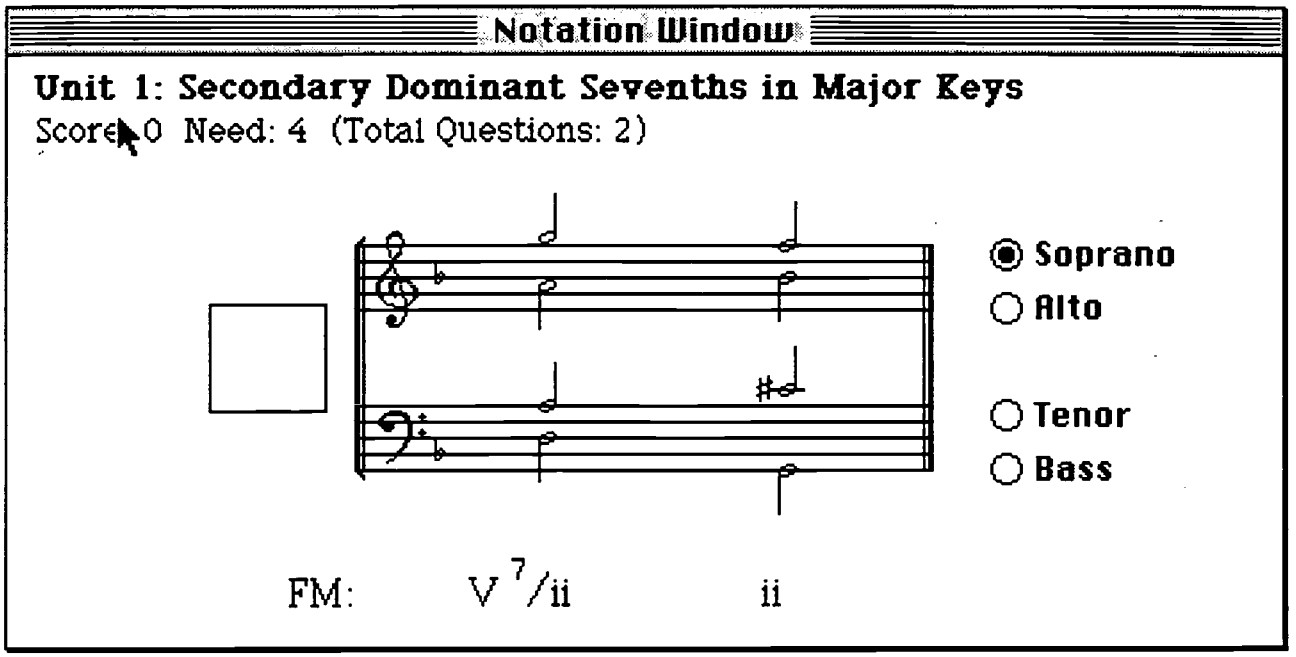
The continuous feedback provided in the box proved to be particularly useful in helping users know when they had positioned the cursor directly over a line of the staff. The margin for error is very slight when attempting to place a musical note upon a staff line. Users were spared the frustration of clicking to position a note upon a staff line only to discover that the cursor position was off by a pixel or two and had entered a note on the staff space directly above or below the desired line.

Error Hierarchy

It is interesting that in many otherwise innovative drill-and-practice computer-based instruction lessons, the error feedback to students is often not very useful or in some cases misleading. In some lessons, students receive very cryptic responses such as: "No, you are incorrect. Try again." or "Yes, you are correct. Very good." All the student knows from that kind of feedback is whether s/he can go on to the next exercise or whether s/he must plod through the exercise again. If the student doesn't have a clue as to why s/he didn't succeed, the negative feedback is rather useless. To add insult to injury, some lessons use "cutsy" verbiage such as: "Wonderful! You are a genius!" when the student is correct, sometimes when such positive accolades are not appropriate.

On the other hand, some lessons give the student who answers incorrectly the answer to the question after the first try whether s/he wants it or not. Studies have shown that students often learn from the errors they make. Thus a student may learn a great deal from feedback given after several tries through an exercise. In the Written Harmony Lessons feedback is given to the student in a unique way.

In the Written Harmony Lessons, we have attempted to allow for individual learning styles by allowing the student to select the type of feedback that s/he gets. When the student responds incorrectly, s/he receives a dialog box containing a matrix from which the student can choose the feedback level. The figure below shows the first attempt by a student to answer a question involving a secondary dominant and its resolution.



As you can see in the figure, the feedback levels allow the student who simply wants to know whether s/he was wrong or right to know that fact in the top level called "Errors." S/he may wish to simply go back to the exercise and think through the problem again. If s/he wants a little more specificity than that, s/he can select the "Error Type." In the example given, it indicates that there are two few different pitches in the first chord and there are non-chord tones in the second chord. This is an indication to the student that s/he is aiming rather wildly in the first chord and only slightly better in the second. If s/he wants more specificity yet, s/he can select the level named "Voices." In this example, the feedback for the first chord ("The error is not related to individual voices") coupled with that for the second chord ("Voices containing non-chord tones: Tenor Soprano") tell the student that when s/he tries again, s/he really needs to think through the process of determining the secondary dominant chord and its resolution chord because until that is done, it is fruitless to worry about voice leading. If the student really wants a great deal of information, s/he may select the "Details" level. In this example, the student is not told the correct chord tones for the first chord but is told instead: "This chord should contain four unique pitches." The student receives that feedback because for the first chord, the student really isn't grasping a very basic concept which is: A seventh chord must contain four different pitches. In the

second chord, the student only had errors in the tenor and soprano voices meaning that s/he had some idea of what the chord should be so s/he is given the pitches of the answer: G Bb D G (bass to soprano). Given the detailed information, the student can fill in the notes of the last chord and then think through what a V7 of that chord is.

In order for the feedback matrix to work, an error hierarchy that would be meaningful had to be established. This hierarchy is one that the music theory teacher should use in giving students feedback in a classroom setting. In the example above, it made no sense to give the student feedback about which voices were incorrect for the first chord when the student did not seem to grasp the basic notion that seventh chords have four unique pitches. Once the student eliminated one of the "g's" in that chord, then feedback about which voices were incorrect would be appropriate. In the class room, where students go to the board to work on problems, the same process can occur. That is, the student who answers the question in the manner of the example, should be first told to think about seventh chords and just how many unique pitches they have. They can be told about the voice errors in the second chord. If after trying again, the student writes a first chord of D Bb A F#, then the teacher can tell the student which voice (the tenor in this case) contains the non-chord tone. If the student actually fixes both chords so that they have correct notes but there are part-writing errors, then the teacher can proceed to give the student information about which voices contain those errors. If the student continues to generate voice-leading problems, then the teacher should give the student the correct answer and go through the logic involved in connecting chords so as to produce smooth conjunct lines.

Even though the error hierarchy delineated above can be transferred to the class room, because a class may have thirty or more students, it is unlikely that a teacher will utilize that hierarchy as efficiently as s/he should because of time constraints which is why the Written Harmony Lessons are becoming such an important tool for harmony instruction.

The project team developed a taxonomy of errors and arranged the members of this taxonomy into a hierarchy. This hierarchy moved from "most severe" to "least severe" and served as the basis for the software to determine which error to present to the student when multiple errors were detected. The hierarchy is shown below.

Intra-Chord Errors

ERR_TOO_FEW_NOTES	Chord doesn't contain enough unique pitches
ERR_TOO_MANY_NOTES	Chord contains too many unique pitches
ERR_ENH_SPELLING	Chord contains a note which is spelled enharmonically

ERR_NON_CHORD_TONE	Chord contains a pitch or pitches which should not be included
ERR_DOUBLED_LEADING_TONE	Chord contains two leading tones, a tendency tone in the key which may not be doubled
ERR_DOUBLING	Chord contains two of the wrong chord tone
ERR_SPACING_WIDE_GAP	The distance between adjacent voices is too great (excluding the bass and tenor)
ERR_SPACING_OVERLAP	Adjacent voices are not in a lowest to highest order
ERR_VOICE_RANGE_HIGH	One of the voices in the chord contains a note which is too high to be performed by that voice
ERR_VOICE_RANGE_LOW	One of the voices in the chord contains a note which is too low to be performed by that voice
ERR_INVERSION	The wrong chord member appears in the bass (lowest) voice

Inter-Chord Errors

ERR_PARALLEL_MOTION Parallel Octaves Parallel Perfect Fifths	A pair of voices in one chord move to form the same interval in the next chord
ERR_CROSSED_VOICES	Voice in one chord is higher than its upper neighbor voice in next chord Voice in one chord is lower than its lower neighbor voice in next chord
ERR_LARGE_LEAP	Inner voice (Alto or Tenor) leaps more than a Perfect 4th
ERR_AWKWARD_LEAP	1.) Voice moves by Augmented 2nd 2.) Voice moves by Diminished 4th
ERR_IDIOMATIC_MOTION	Non-stylistic resolution of a "tendency" tone – leading tone, seventh of a chord, etc.

The division of the hierarchy divides errors into those which occur within a single chord (labeled intra-chord) and those which involve the connection between two chords (labeled inter-chord). Intra-chord errors are judged to be more severe than inter-chord errors.

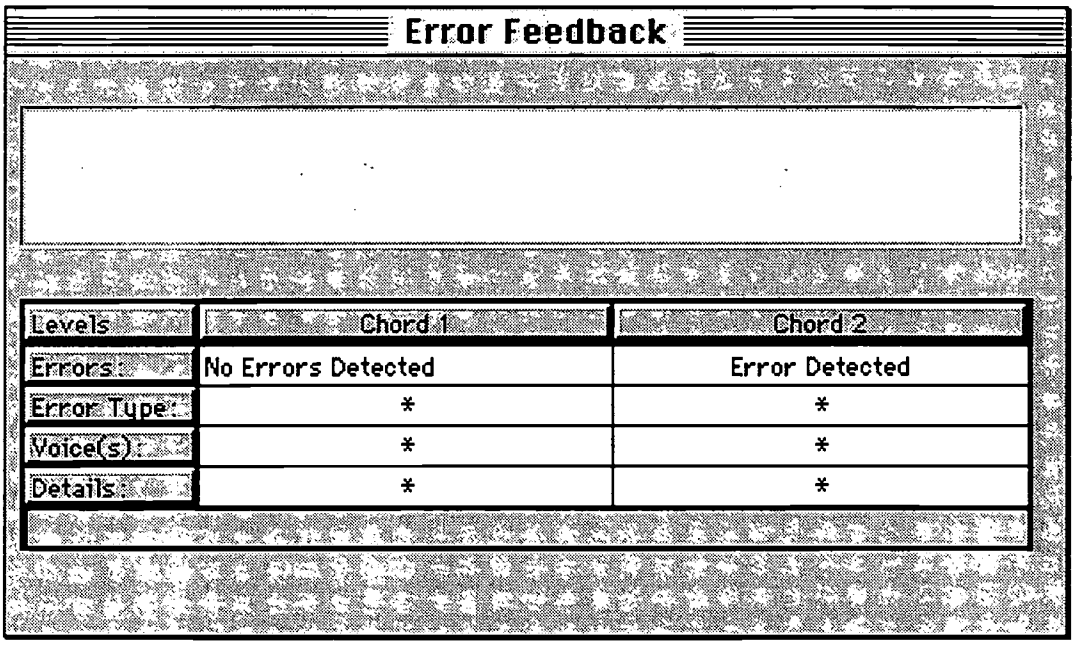
Layered Feedback

The process of helping users locate errors in their work submitted for evaluation is central to the mission of the software if users are to develop the "self-analytic" skills needed to locate errors in their work when functioning as musicians away from the software. In order for students to develop their own error detection skills, it is important that the feedback they receive not initially divulge the exact location and nature of an error. This project developed a method of feedback delivery which provides feedback in four layers. As one moves through the layers,

increased specificity is provided as to the location and nature of the error. The function of each layer is shown below.

Layer #1:	YES / NO judgment as to the correctness of a chord
Layer #2:	Type of error present in the chord
Layer #3:	The voice(s) involved in the error
Layer #4:	Suggested action or most explicit explanation of the error

An example of the appearance of the feedback window is shown below. In the table, the individual chords form the columns of the table and the feedback layers form the row. Users select the feedback they desire by double-clicking in the cell which is at the intersection of the desired chord and the feedback layer.



The feedback retrieval mechanism selected by the project allows users to reach any layer of feedback at any time without having met a prerequisite of having read the preceding layer(s) of feedback. This decision reflects the general project belief in user control of the learning environment and its resources.

Anecdotal evidence collected during user testing, however, indicated that the lack of enforced "prerequisites" prompted some users to proceed directly to the "lowest" (most informative) feedback layer. This method of operation does not help users to develop their own detection skills.

Foundation for FIPSE Jazz Project

The technical work completed for the "Computer Lessons for Written Harmony" project has provided a solid footing for the work being done for the FIPSE jazz project (FIPSE Project #P116A30097). In particular, three areas of

work on this project have been directly utilized by the jazz project. These areas are data structures, musical generators, and notation input.

Data Structures. The data structures devised to represent musical constructs are being used directly by the jazz project. The structures for representing musical notes, intervals, scales, and chords were sufficiently flexible to allow their reuse without significant modifications.

Musical Generators. The software routines developed by this project for the generation of musical scales and chords are serving as the basis for the scale and chord generators used in the jazz project.

Notation Input. The work done by the Written Harmony project to design and implement a music notation input method is being reused by the jazz project without modification. This method of notation input is proving as effective in this new environment as it was in its original incarnation.

Challenges

Dual Platform Development

As a goal first specified in the original proposal, the project team wanted the software developed to run on both the Macintosh and Windows platforms. With this goal in mind, a development tool called XVT (XVT Software, Inc.) was chosen. As a bonus, this development tool also supports a variety of UNIX "flavors" which gives us the potential of moving our source code to that operating system in necessary in the future. As an aid in the display and editing of tabular-based information, a development library called XI (ORCA Software, Inc.) was chosen by the project team. This tool is designed to work with XVT and thus supports all of the platforms discussed above.

Our experience with these multi-platform development tools was mixed. During the course of the Written Harmony project, the XVT software underwent three significant revisions. These revisions involved changes to the core architecture of the product. While each of these revisions corrected deficiencies in the existing product and added new functionalities, they also created the necessity of revising and modifying existing source resulting in a "three steps forward, two steps back" situation.

In fairness, the XVT development environment did provide a solid core of functionality to develop applications for both Windows and the Macintosh. The applications created did indeed have the "look and feel" of the native platform. The XVT tool was less helpful when the user interface required more advanced

elements such as pop-up menus, etc. The basic aspects of the user interface (creation of windows, menubar management, dialogs, etc.) were handled quite acceptably.

Remote Test Sites

The three remote test sites (Illinois State University, Indiana University, and University of Kentucky) selected for the Written Harmony Lessons are excellent institutions with reputations for excellence in the area of music theory. They were also very cooperative with us and were willing to help us out in any way they could. However, only Indiana University was actually able to deliver the software to its students. One reason that Illinois State and the University of Kentucky were not able to help us was because they had a difficult time getting compatible hardware for the software even though discussions with the contacts at those institutions led us to believe that the hardware was not an issue. A second reason that those institutions were not able to test the software was because the professors who were our contacts at those institutions did not have direct control over the instructors in charge of the sections of the harmony courses targeted to test our materials. So even though the contact people had promised that our materials would be tested during a certain period of time based on when they thought the individual theory sections were covering certain segments of material, the instructors in charge of the harmony sections were not actually teaching those segments at the appropriate time. Thus, the software was not tested at those institutions. The contacts were very apologetic and are still willing to test the software next year. We plan to follow through with their offer.

The problems that we have had with our remote sites have implications for the selection and use of remote sites in the future. First of all, we will probably select sites closer to us. In our geographical area, there are quite a few very fine institutions. Their close proximity would allow us to visit them and make sure that the hardware available at those institutions is really compatible with our software. If not, the close proximity would allow us to bring hardware to them if necessary. Secondly, we will select sites where the contact people are the actual instructors of the courses. That would allow them to make sure that the students were presented with the software at the appropriate time in the during the semester.

E. Evaluation

Types of Data

Data are being collected to determine both improvements in student written harmony skills and changes in attitudes toward written harmony. For the first, we administer comprehensive tests in written harmony at the beginning and end of each year. Second, we give an affective questionnaire to judge changes in students' attitudes toward the written harmony course. These data have been collected over the past four years and will continue to be collected under an interrupted time-series analysis model.

Data Collection Procedures

Skills

Two comprehensive exams (see Appendix C), testing a variety of written harmony skills, are given to all students in MUSC 195 and 196 at the University of Delaware at the beginning and end of each semester during the regular school year. The tests cover four voice part-writing using triads and seventh chords, chromatic part writing, and analysis. Between twenty and thirty-five students are tested each year.

The same diagnostic tests are given each time. Each student is identified by a number so that the examiner is not aware of the student's identity when scoring the exam. The complete set of the instructions used for administering the written harmony test is given in Appendix D.

Because grading the above exams can be a subjective process, all pre- and post-treatment exams will be graded at the same time for consistency. Graders will not know student names, which exams are pre- or post-treatment, or which exams were given at the beginning or end of the school year.

Attitudinal

The survey questionnaire (see Appendix B) consists of twenty-five questions to determine students' attitudes toward factors such as self-confidence, study habits, computer phobia, anticipated grade, and perceived improvement in written harmony. Questions are worded both positively and negatively to prevent students from haphazardly marking similar scores down a column. Redundant questions eliciting attitudes about the same area are included as reliability checks. Some of the questions are neutral, and were given only to elicit student demographic information and attitudes.

Data Evaluation

Because of the time-series model being used, the results below are preliminary. Data must be collected over at least two more years to obtain reliable data. Also, delays in completing the final version of the treatment software have delayed the gathering of meaningful data.

Skills

Not enough data have been collected at the University of Delaware to complete the skill-based portion of the evaluation. We currently have all the exams administered from the 1991 fall semester through the 1995 spring semester. Data will be collected for at least two more years for complete comparison.

We attempted an interim study to determine whether portions of the software covering secondary dominants would be effective in isolation. A specialized test was devised (Appendix E) which tested only on that specific aspect of part-writing and analysis. Cooperating schools were asked to administer a pre-test, allow an experimental group of students to use the selected portions of the software for a period of five weeks, and then administer the same test as a post-test. Control students studied the materials in their usual way.

Unfortunately, two out of three cooperating schools, to whom the exams and software were sent, for a variety of reasons, were not able to satisfactorily deliver the software and administer the pre- and post-tests. We received back a total of twenty completed pre- and post-tests. This number was too small to apply any meaningful statistical analyses.

Attitudinal

A summary graph of data from the attitudinal questionnaires is in Appendix A. The scores of negatively-worded questions have been reversed to provide consistent scoring across the questionnaire. For example, question number 1, "I enjoyed first-year harmony." is worded positively. Question number 4, "I was often discouraged in first-year harmony." is negatively worded. Those questionnaires that were inconsistent in the reliability question checks were eliminated. For example, questions 2 and 9 ask respectively whether the student expects to get an "A" or a "C" or lower in written harmony. Inconsistent answers to these questions would indicate a unreliable questionnaire.

Evaluation Results

Skills

None available

Attitudinal

The bar graph in Appendix A summarizes data collected from the attitudinal surveys over the past four years. As mentioned above, the bar values for negatively-worded questions have been reversed so that attitudes favorable toward written harmony will correspond to positively-worded questions. In addition, the scores have been standardized from -1 to +1, with positive scores indicating a favorable attitude. For example, if the all answers to positively-worded question number 1, "I enjoyed first-year harmony." had been a 7, the average would be a 7 which would indicate the most extreme degree of unfavorability. This would be represented by a "-1" in the graph.

The actual mean response number (non-standardized) for question number 1 was 2.54, or not quite halfway from a neutral "4" to favorable "1". Therefore, the standardized mean is just less than .5, which indicates a score almost halfway between a neutral ("0") and completely favorable ("1"). When post-treatment scores are collected, improvement on any single question will be shown by a positive increase in the height of the bar for that question.

We were surprised (and pleased) to discover the generally favorable attitude toward written harmony indicated by students, even before the software is available. While these positive scores will make treatment gains more difficult to achieve, they indicate that current teaching practices are working, at least in terms of student acceptance. The overall mean score (with negatively-worded questions reversed) was 3.08 (a standardized score of .31).

Dissemination

Project personnel made two presentations concerning project activities during the project period. Details concerning these presentations are shown below.

- "The Design and Development of a Computer-Based Harmony Coach"
  Presentation at 1993 National Conference on Technology in Music Instruction
  Thirty-Sixth Annual Meeting of The College Music Society
  Minneapolis, Minnesota
  October, 1993

- "Sight-Singing and Written Harmony Projects"
  1993 FIPSE Project Director's Meeting
  Washington, D.C.
  October, 1993

Because the robust data collection capabilities devised for the Written Harmony Lessons provide for the storing of detailed information on questions presented and on student answers, we intend to learn a great deal about learning styles and

implications for the teaching of part-writing, harmonization, and analysis. We intend to publish the results of the studies done in these areas in Computers in the Humanities, the Journal of Research in Music Education, the Bulletin of the Council for Research in Music Education, the Journal of Computer-Based Instruction, Spectrum: Journal of the Society for Music Theory, and the Journal of Music Theory Pedagogy. In addition, we intend to report findings of studies at such conferences as the Association for Technology in Music Instruction (ATMI), Music Educators National Conference In-Service Workshop, and the Association for the Development of Computer-Based Instructional Systems (ADCIS).

Continuation

It is our intent to market the Written Harmony Lessons. We believe that they will be purchased by high schools and colleges for their music theory curricula as well as individuals because the Written Harmony Lessons are unique. They are a comprehensive drill-and-practice series covering diatonic and chromatic harmony and testing harmonization and part-writing skills. Other music theory packages may cover some of the skills but not all the skills covered by the Written Harmony Lessons. In addition, the interface of the Lessons is unique and easy to use. Also, the feedback matrix is also unique and, as explained above, allows for individual learning styles.

In Version Two of the Written Harmony Lessons, we intend to include non-harmonic tones in our examples. They will be added to the exercises in accordance with the instructor's wishes through a table of non-harmonic tones. The addition of these tones will make for more musical examples than are possible through examples utilizing strictly chordal sonorities. In addition, sonorities greater than a seventh (9ths, 11ths, and 13ths) will be possible in the lessons in Version Two.

F. Summary and Conclusions

The Written Harmony Lessons were developed to help students acquire the very important skills of harmonization, part-writing, and analysis of music. Although many drill-and-practice software packages have been written that address the fundamental skills, none exist that do a good job with the more complex skills of harmonization, part-writing, and analysis of music. It is our belief that the Written Harmony Lessons will go a long way to increasing the musicianship for students at the University of Delaware and other Departments and Schools of Music around the country. Not only do the Written Harmony Lessons address complex skills, but they utilize a unique and user-friendly interface and incorporate a feedback

matrix which accommodates the various learning styles of students everywhere. The research we conduct as students work with the lessons will provide valuable information about how students learn to harmonize, write the voices in a four-part context, and how they go about the process of analysis. In testing the software, we have already learned important information about better ways of presenting this material in the context of a conventional classroom.

The software used in the development of the Written Harmony Lessons was a springboard for the Interactive Jazz Theory Lessons, currently being developed through another grant from FIPSE. We forsee the software being used for other music theory projects as well. The three-year project has been a great learning process for all of us working on the development of the software. Even though we each had individual roles in the creation of the software -- Michael Arenson as content specialist, Steven Bertsche as lead programmer, and Gary Feurer as evaluation expert -- we soon found that those three areas were inextricably intertwined and that it was vital that we work closely together taking advice from each other to create the superior product that resulted. The synergy of the team has allowed us to be extremely productive in the creation of the Interactive Jazz Theory Lessons and will undoubtedly be a crucial aspect of many successful projects in the future.

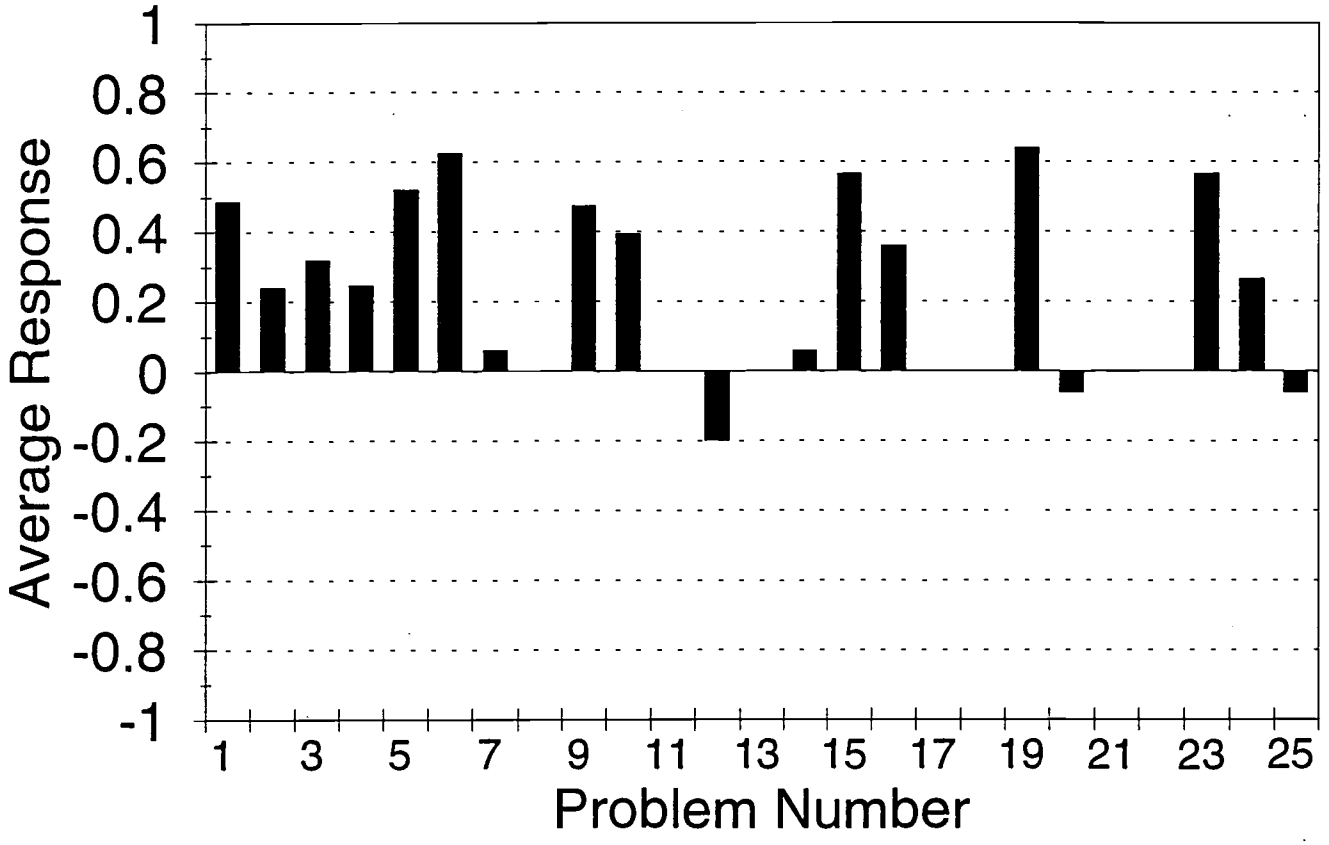
APPENDICES

Appendix A:

Attitudinal Questionnaire Results

UD Written Harmony Attitudinal Survey

Avg. Response (Corrected/Standardized)



Appendix B:

Attitudinal Questionnaire

Written Harmony Summary Questionnaire

Please circle the number that most closely matches your current feelings.

		Strongly Agree			Neutral			Strongly Disagree
1.	I enjoyed first-year harmony.	1	2	3	4	5	6	7
2.	I think I should get an A in this course.	1	2	3	4	5	6	7
3.	I often did exercises from the textbook with a friend.	1	2	3	4	5	6	7
4.	I was often discouraged in first-year harmony.	1	2	3	4	5	6	7
5.	Harmony writing is an important skill for me as a musician.	1	2	3	4	5	6	7
6.	I grew more confident of my harmony writing abilities as the course progressed.	1	2	3	4	5	6	7
7.	I had difficulty doing the written harmony homework by myself.	1	2	3	4	5	6	7
8.	I feel intimidated when doing exercises at the blackboard in front of the class.	1	2	3	4	5	6	7
9.	I will probably receive a grade of C or lower in this course.	1	2	3	4	5	6	7
10.	I consider myself an extremely competent musician.	1	2	3	4	5	6	7
11.	This questionnaire is a real pain to fill out.	1	2	3	4	5	6	7
12.	I have trouble finding enough time to do the assigned drills in the textbook.	1	2	3	4	5	6	7
13.	My instructor was very helpful whenever I had any problems.	1	2	3	4	5	6	7
14.	It is a good idea to include computer-based instruction in first-year harmony.	1	2	3	4	5	6	7
15.	I am a much better musician as a result of having taken first-year harmony.	1	2	3	4	5	6	7
16.	Skills learned in first-year harmony improved my ear-training and sight-singing skills.	1	2	3	4	5	6	7
17.	I worked very hard in first-year harmony.	1	2	3	4	5	6	7
18.	I had difficulty doing the exercises from the textbook without assistance of any kind.	1	2	3	4	5	6	7
19.	I enjoy attending college.	1	2	3	4	5	6	7
20.	Learning harmony was my most difficult musical challenge this year.	1	2	3	4	5	6	7
21.	Music is the most important thing in my life.	1	2	3	4	5	6	7
22.	The diagnostic tests were a waste of my time.	1	2	3	4	5	6	7
23.	Learning historical part-writing rules is a waste of time for contemporary musicians.	1	2	3	4	5	6	7
24.	My musical performances are better when I have first analyzed the music.	1	2	3	4	5	6	7
25.	Part-writing is more difficult for me than analysis.	1	2	3	4	5	6	7

Appendix C:

Music Pre/Post Test Forms

MUSIC THEORY

RESEARCH EXAMINATION

PART B

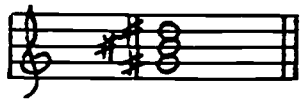
This is a continuation of part A. Do not open this booklet until told to do so. Mark all of your responses on the computer form provided. DO NOT MARK IN THIS BOOKLET.

MUSIC THEORY RESEARCH EXAMINATION

PART B

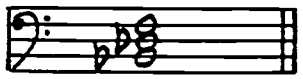
XIII.

1. The triad below is what quality?



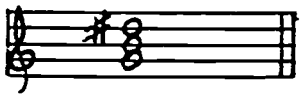
a) Major. b) Minor. c) Diminished.
d) Augmented. e) None of the above.

2. The triad below is what quality?



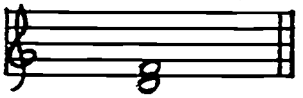
a) Major. b) Minor. c) Diminished.
d) Augmented. e) None of the above.

3. The triad below is what quality?



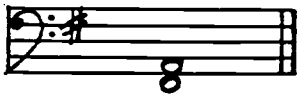
a) Major. b) Minor. c) Diminished.
d) Augmented. e) None of the above.

4. The two notes below are the 3rd and 5th of a <u>diminished</u> triad. What is the root?



a) G-sharp. b) G. c) B. d) B-flat.
e) B-sharp.

5. The two notes below are the root and 3rd of a <u>minor</u> triad. What is the 5th?

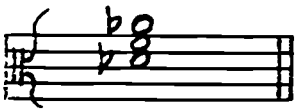


a) D. b) D-sharp. c) D-flat.
d) C-sharp. e) C.

6. The quality of the diatonic triad on the fourth degree of a major scale is:

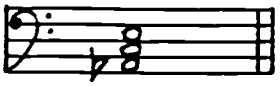
a) Major. b) Minor. c) Diminished. d) Augmented.

7. The triad below is what quality?



a) Major. b) Minor. c) Diminished. d) Augmented.
e) None of the above.

8. The triad below is what quality?

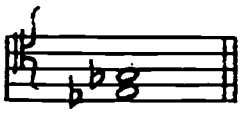


a) Major. b) Minor. c) Diminished.
d) Augmented. e) None of the above.

9. The Augmented triad with E as its fifth has as its root:
a) A. b) A-sharp. c) A-flat. d) A double-flat. e) G-sharp.

10. The major triad with A-flat as its third has as its fifth:
a) C-flat. b) C. c) B. d) F-flat. e) F.

11. The two notes below are part of a major triad. What other note is needed?



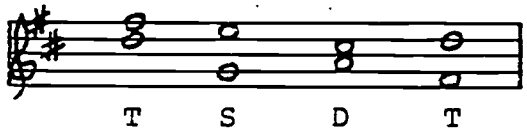
a) B. b) B-flat. c) C. d) C-flat. e) None of the above.

12. The diminished triad with G as its third has as its fifth:
a) B. b) A-sharp. c) B-sharp. d) B-flat. e) B-double flat.

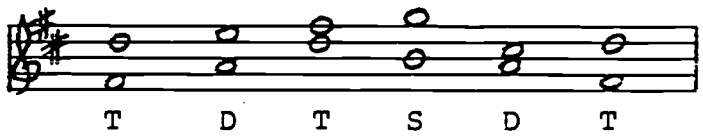
XIV.

13. In which of the following examples is the underlying harmonic function not correctly analyzed? (T= tonic function, S= subdominant function, and D= dominant function)

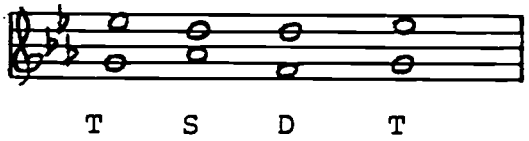
a)



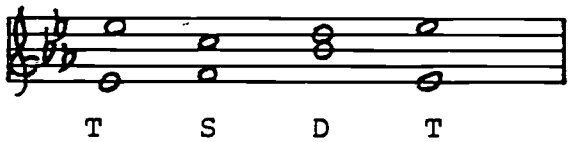
b)



c)

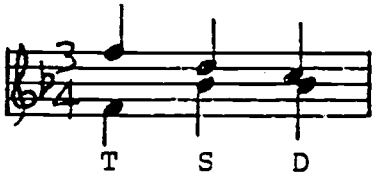


d)

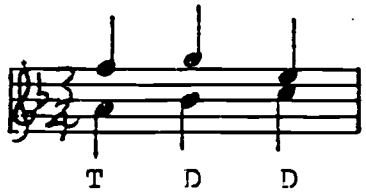


14. In which measure of the following phrase is the harmonic function analysis incorrect?

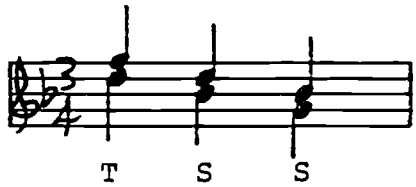
a)



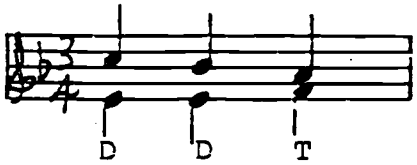
b)



c)

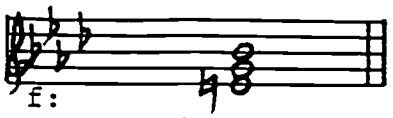


d)



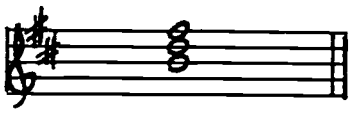
XV.

15. Select the correct chord symbol.



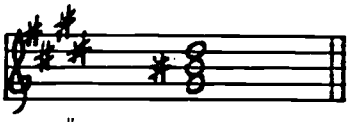
a) V b) VII c) vii° d) VII+ e) vii

16. Select the correct chord symbol.



a) IV b) V c) VI d) vi e) iv

17. Select the correct chord symbol.



a) v b) V c) v° d) #V e) V+

18. The triad built on the seventh scale-degree is called the:

a) dominant. b) supertonic. c) submediant. d) tonic.
e) none of these.

19. The root of the subdominant triad is located:

a) a 2nd above the dominant. b) a 2nd below the tonic.
c) a 5th below the tonic. d) a 3rd below the leading-tone.
e) none of these.

20. Which of the following is an "opening" progression?

a) I ii V I b) I IV I c) I V d) IV I

21. The three primary triads are located on the tonic, a 5th above the tonic, and a 4th below the tonic.

a) true b) false

22. In a major key, all primary triads are major.

a) true b) false

23. Which is the secondary triad related to the tonic?

a) mediant. b) submediant. c) leading-tone.
d) supertonic. e) none of these.

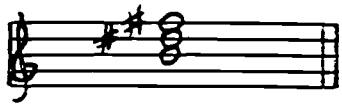
24. Which is the secondary triad related to the subdominant?

a) mediant. b) submediant. c) leading-tone.
d) supertonic. e) none of these.

25. Which primary triad has two secondary triads?

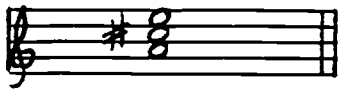
a) mediant. b) subdominant. c) submediant.
d) tonic. e) none of these.

26. Which figured bass symbol is correct?



a) 5# b) $\frac{\sharp}{3}$ c) $\frac{\sharp}{\#}$ d) $\frac{5}{3}$ e) $\sharp$

27. Which figured bass symbol is correct?



a) $\not{6}$ b) $\frac{5}{3}$ c) $\frac{6}{\#}$ d) # e) $\not{5}$

28. Which is the secondary triad related to IV?

a) vii° b) iii c) vi d) ii e) V

29. Which is the secondary triad related to V?

a) iii b) I d) ii d) vi e) IV

30 Which is the primary triad related to vii°?

a) ii b) iii c) IV d) I e) V

31. Which statement is correct?

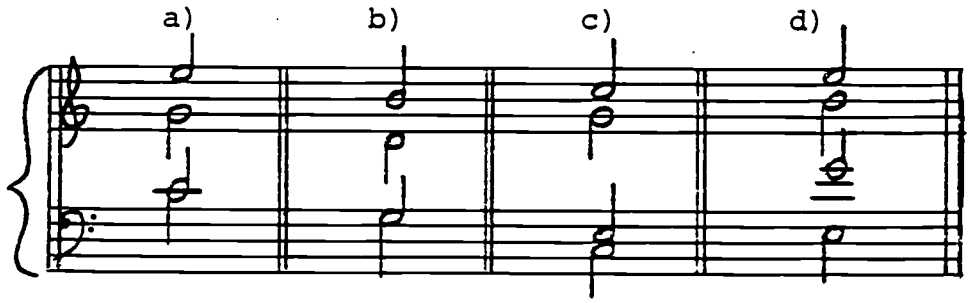
a) When no figured bass symbol is used, a major triad in root position is implied.
b) a slash through a number in the figured bass does not refer to a specific chromatic sign (such as a sharp, flat, natural, etc.).
c) Both statements (a&b above).
d) Neither statement is correct.

32. Figured bass symbols refer to specific intervals:

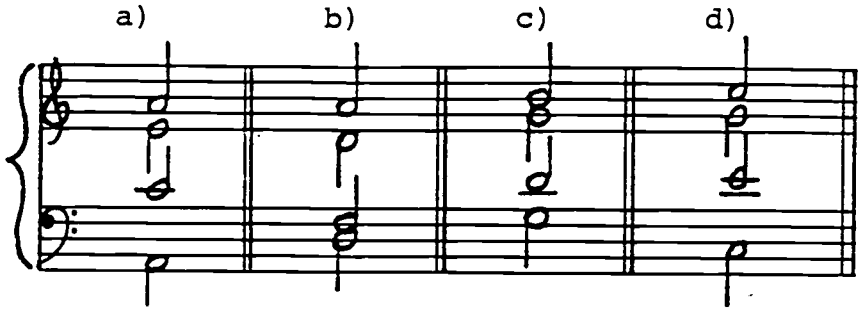
a) above the chord root. b) above the lowest note.
c) above the key-note. d) above the 3rd of the chord.
e) below the lowest note.

XVI

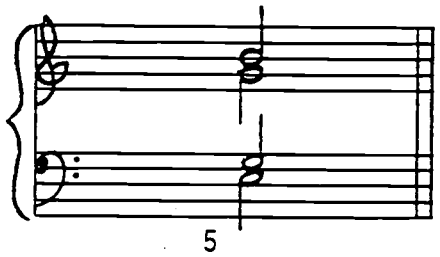
33. Which chord is in close structure?



34. Which chord is in open structure?

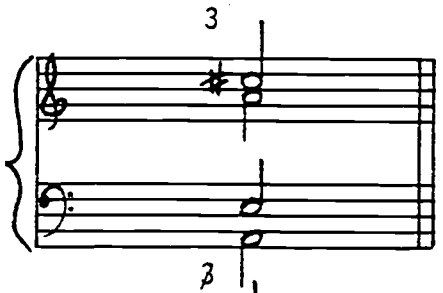


35. What error is demonstrated below?



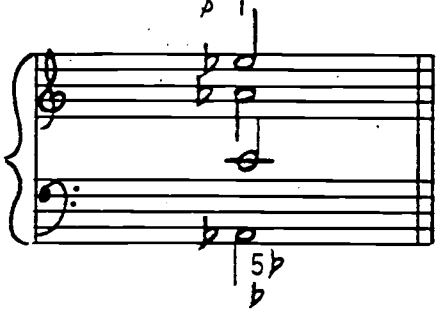
a) Excessive interval between voices.
b) Figured bass symbol not realized.
c) Voice out of range.
d) Incorrect doubling.
e) No error present.

36. What error is demonstrated below?



a) Excessive interval between voices.
b) Figured bass symbol not realized.
c) Voice out of range.
d) Incorrect doubling.
e) No error present.

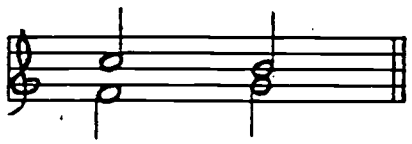
37. What error is demonstrated below?



a) Excessive interval between voices.
b) figured bass symbol not realized.
c) Voice out of range.
d) Incorrect doubling.
e) No error present.

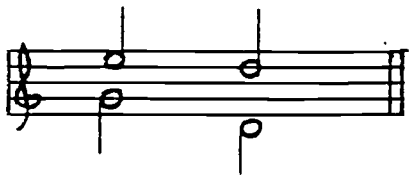
XVII

38. The example below demonstrates:



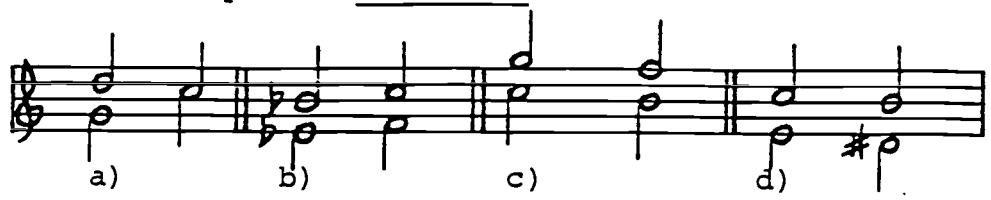
a) Similar motion.
b) Parallel motion.
c) Oblique motion.
d) Contrary motion.
e) Motion sickness.

39. The example below demonstrates:



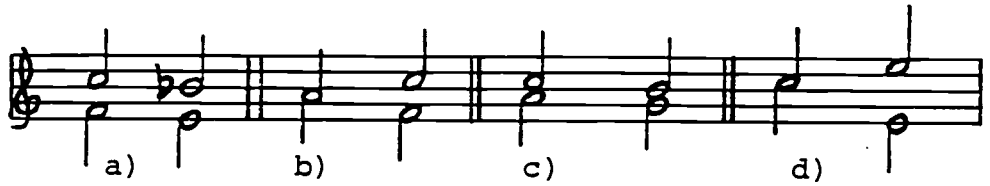
a) Similar motion.
b) Parallel motion.
c) Oblique motion.
d) Contrary motion.
e) Lack of motion.

40. Which is an example of incorrect motion?



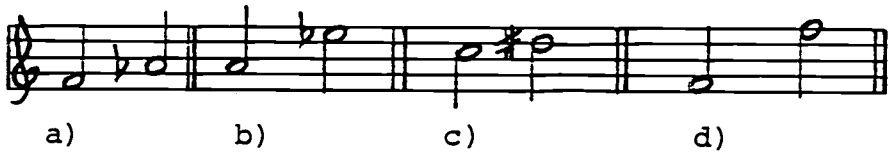
e) All are correct.

41. Which is an example of incorrect motion?

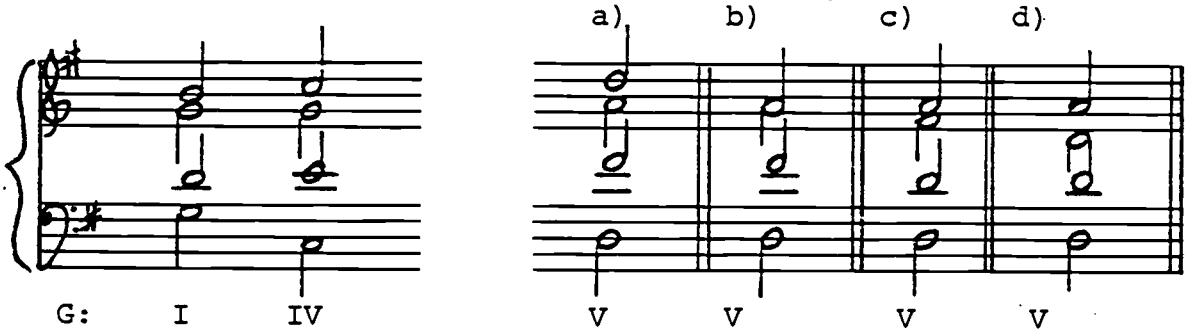


e) All are correct.

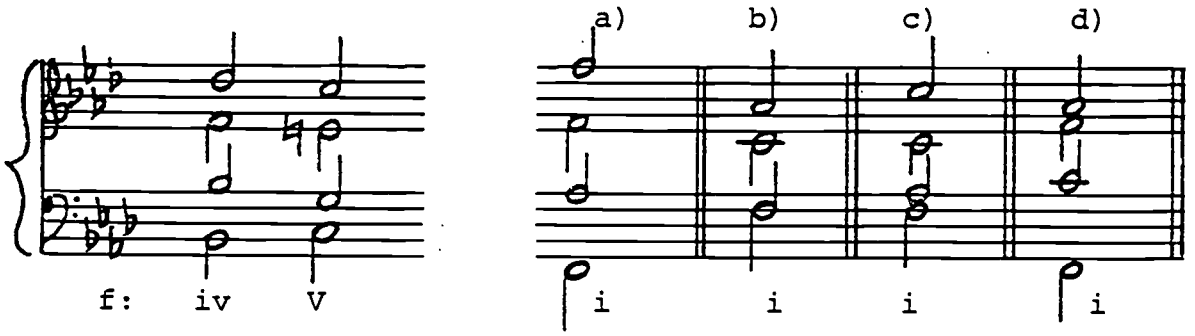
42. Which interval is undesirable in melodic writing?



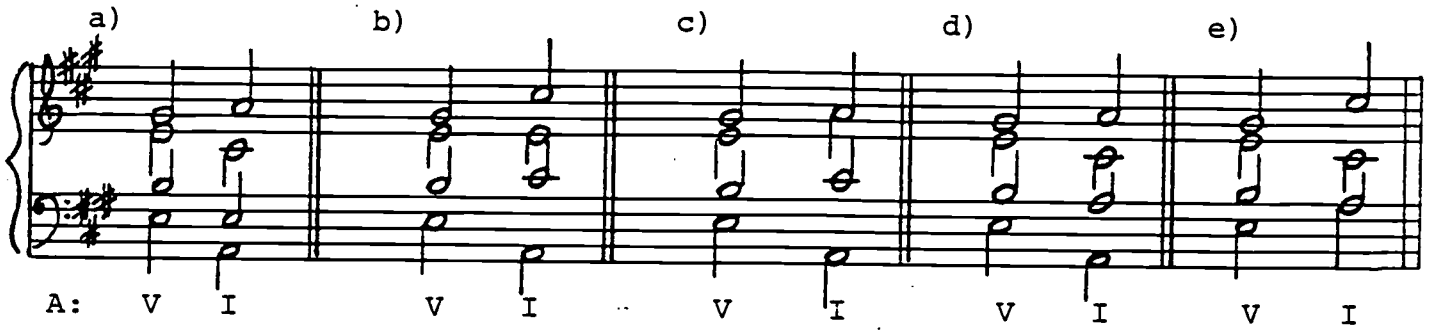
43. Which chord prcduces the best voice leading?



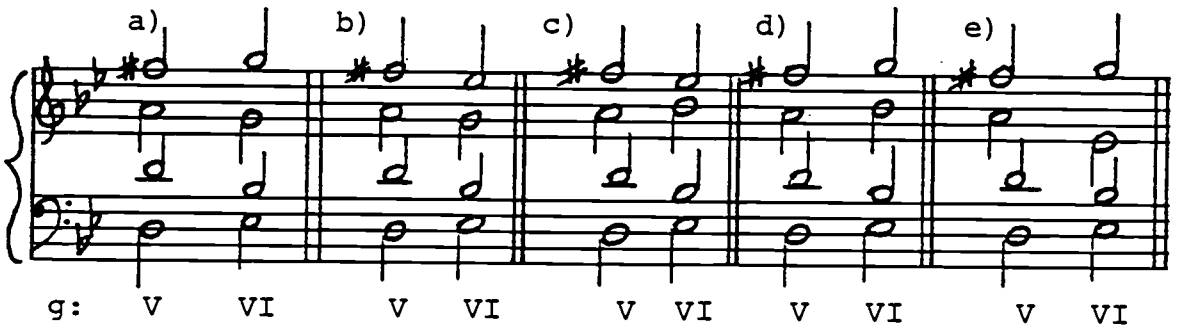
44. Which chord produces the best voice leading?



45. Select the preferred version.



46. Select the preferred version.



XVIII

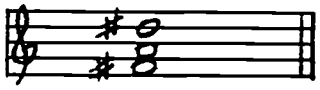
47. When a triad is in first inversion, which factor is in the bass?

a) root. b) 3rd. c) 5th. d) 7th.

48. A triad with the 5th in the soprano is called a six-four chord.

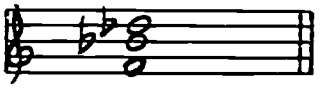
a) true b) false

49. Which is the correct figured bass symbol?



a) $\begin{matrix}\not{6}\\4\end{matrix}$ b) $\begin{matrix}\not{6}\\\#\end{matrix}$ c) $\begin{matrix}\not{6}\\3\\\#\end{matrix}$ d) $\not{6}$ e) none of these.

50. Which is the correct figured bass symbol?



a) $\begin{matrix}\flat 6\\\flat 4\end{matrix}$ b) $\begin{matrix}\flat 6\\\flat 3\end{matrix}$ c) $\begin{matrix}6\\4\end{matrix}$ d) $\flat 6$ e) 3

51. In four-part writing, when a major or minor triad is in first inversion it is usual to:

a) double the root. b) double the soprano. c) double the 3rd.
d) double the bass. e) double the 5th.

52. In four-part writing, when a major or minor triad is in second inversion it is usual to:

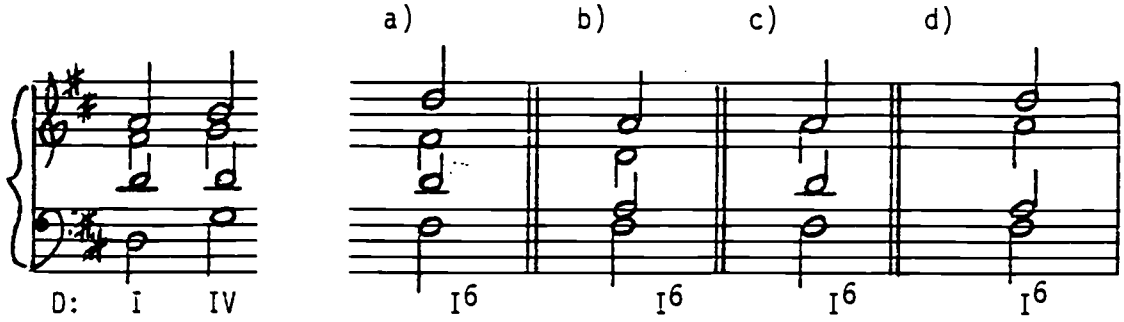
a) double the root. b) double the 3rd. c) double the soprano
d) double the bass. e) double the tenor.

53. Diminished triads appear most frequently in;

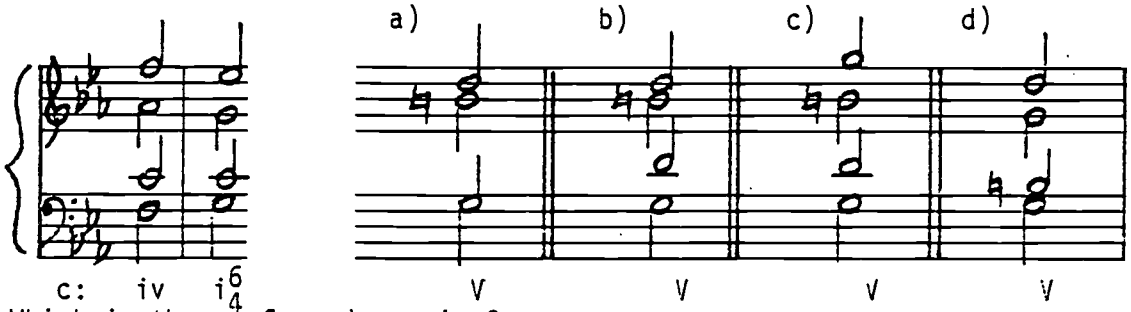
a) root position. b) first inversion. c) second inversion.

d) any inversion. e) none of the above

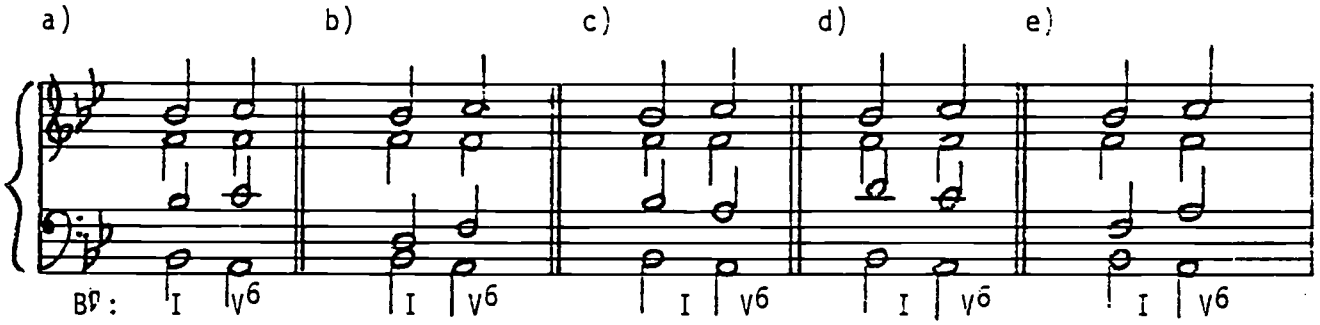
54. Which chord produces the smoothest and most correct voice leading?



55. Which chord produces the smoothest and most correct voice leading?

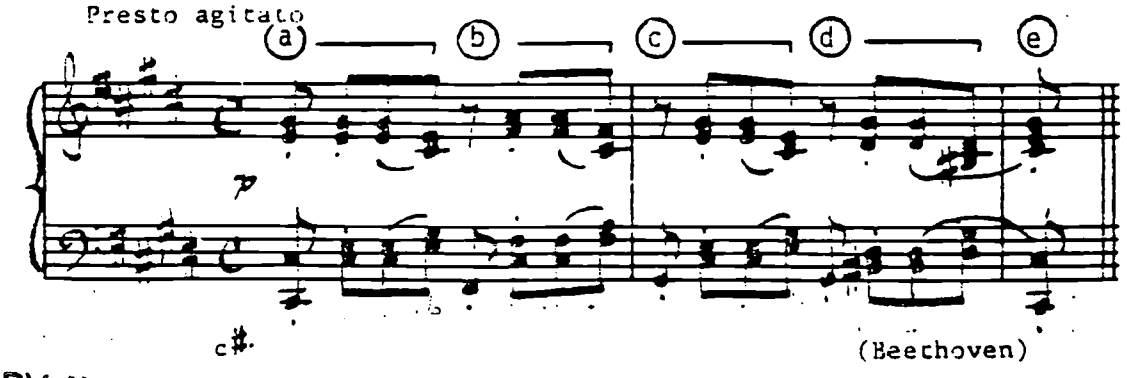


56. Which is the preferred version?



XIX

QUESTIONS 57 - 61 REFER TO THE EXAMPLE BELOW:



57. This example contains no first inversion triads.
    a) true b) false

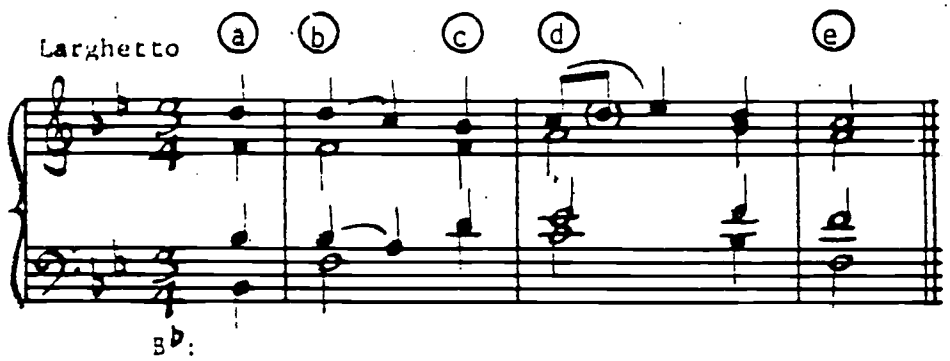
58. Which chord is in second inversion?

59. What type of six-four chord is illustrated in the previous example?
    a) embellishing b) cadential c) passing
    d) arpeggio e) pedal

60. The cadence in the previous example is:
    a) perfect plagal. b) imperfect authentic. c) half.
    d) deceptive. e) perfect authentic.

61. The previous example contains no secondary triads.
    a) true b) false

QUESTIONS 62 -67 REFER TO THE EXAMPLE BELOW:



62. How many first inversion triads does this example contain?
    a) 1 b) 2 c) 3 d) 4 e) 5

63. Which chord is in second inversion?

64. The six-four chord contained in the above example is best classed as which type?
    a) embellishing. b) cadential. c) passing.
    d) arpeggio. e) pedal.

65. The cadence in the example above is:
    a) imperfect authentic. b) imperfect plagal. c) half.
    d) phrygian. e) deceptive.

66. Which chord is a diminished triad?

67. Chords b, d, and e all have dominant function (above example).
    a) true b) false.

68. Which is an authentic cadence?

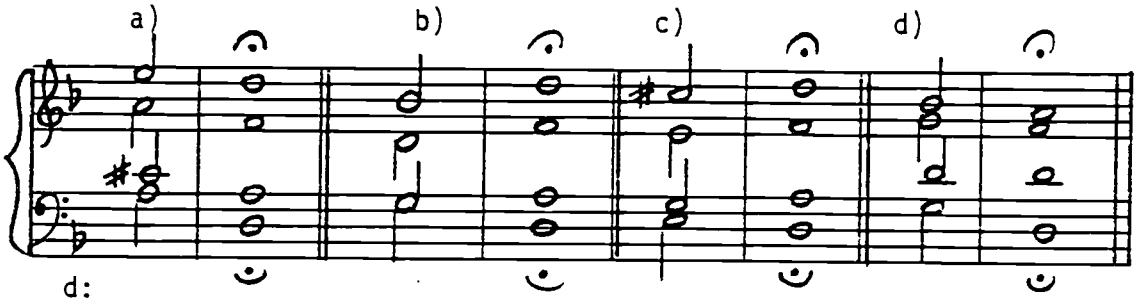
a) IV - I b) IV - V c) V - vi d) vii° - I

e) None of these.

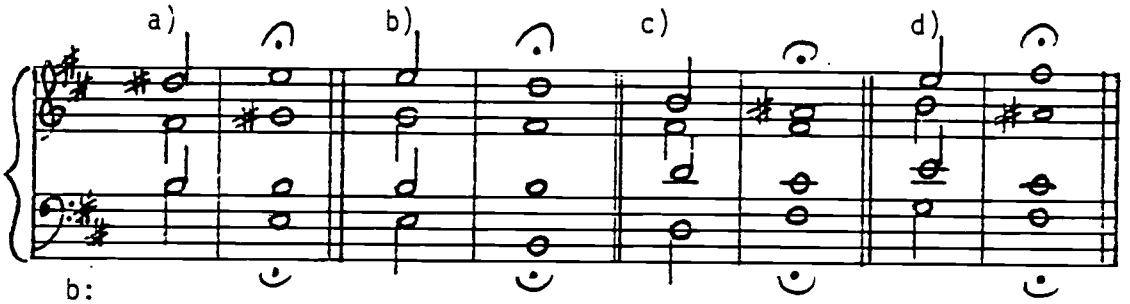
69. Which of the following represents a half cadence?

a) IV - I b) V - I c) V - vi d) iv - V e) none of these.

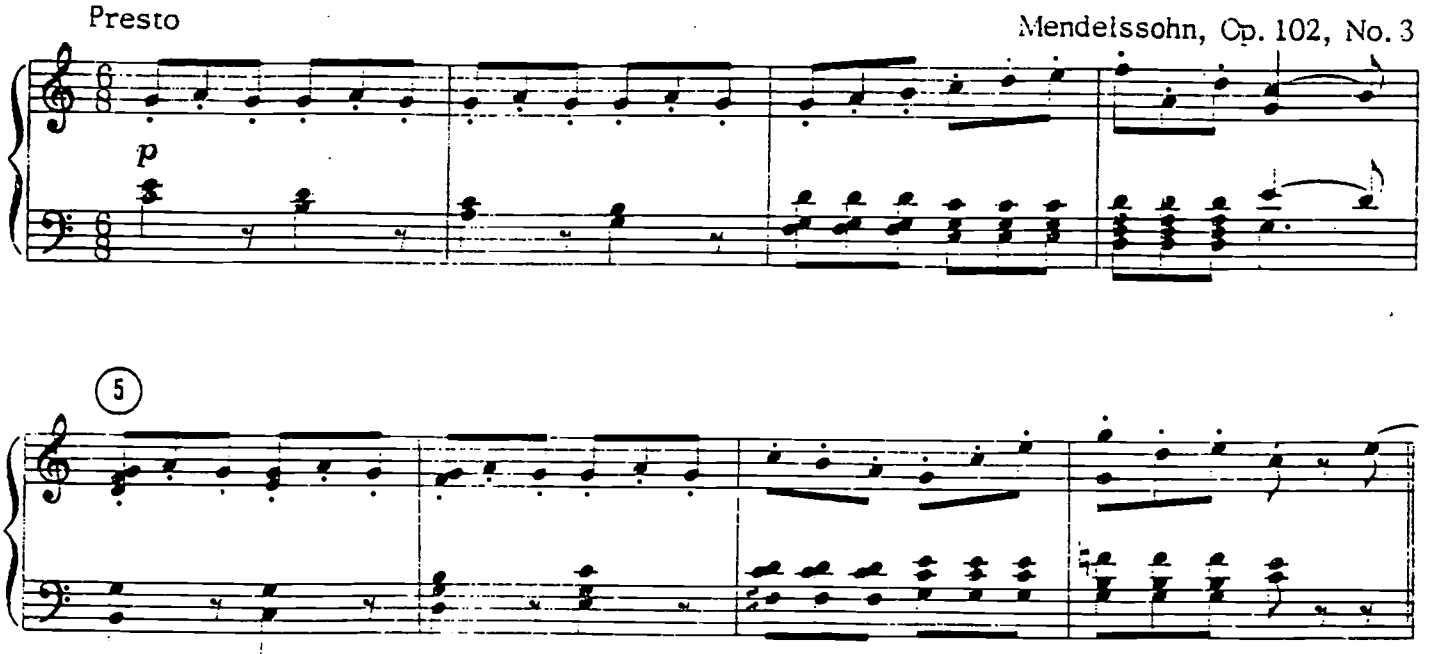
70. Which is a perfect plagal cadence?



71. Which is a Phrygian cadence?



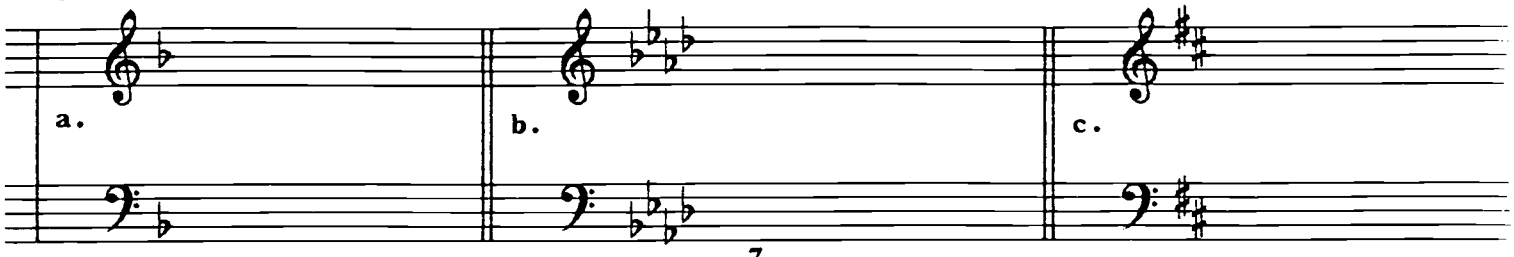
XX QUESTIONS 72 - 74 REFER TO THE EXAMPLE BELOW.



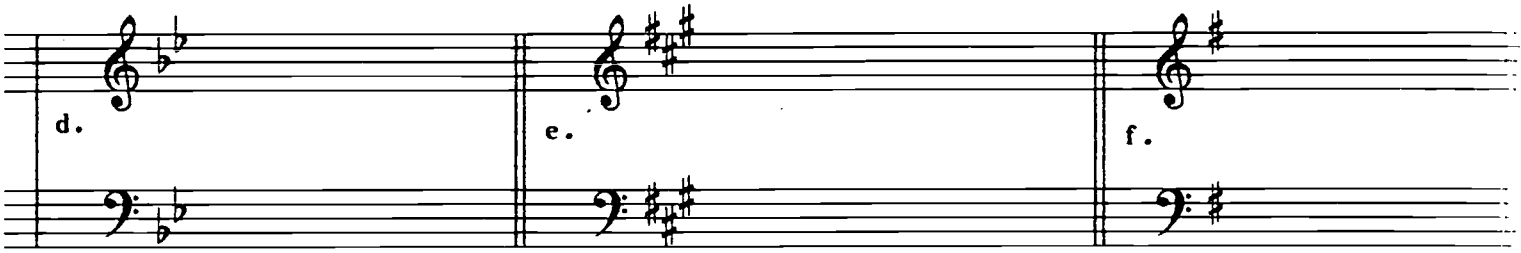
Chromatic Harmony Test

Name: _____

I. Write the chords indicated by the Roman Numerals and resolve each. When a blank appear fill it in:

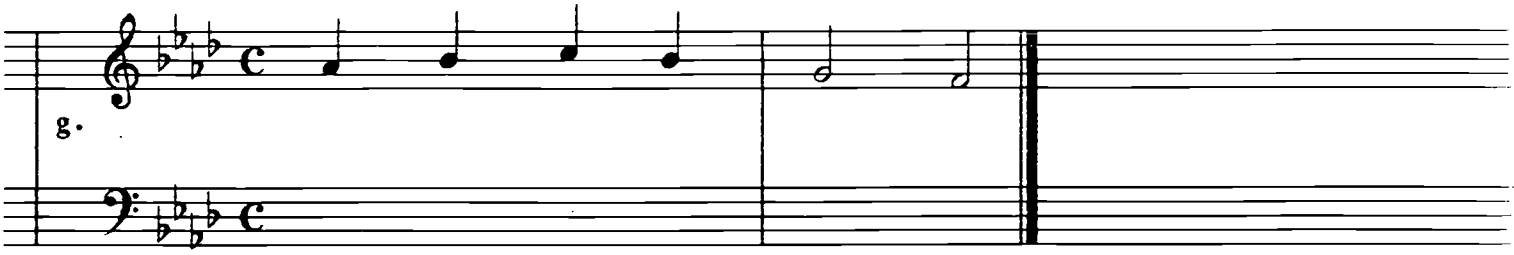


D Mi: iv7 _____ Ab: V^{7}_{bb5}/IV _____ B Mi: $1T^{6}$ (Lowered 2nd) _____



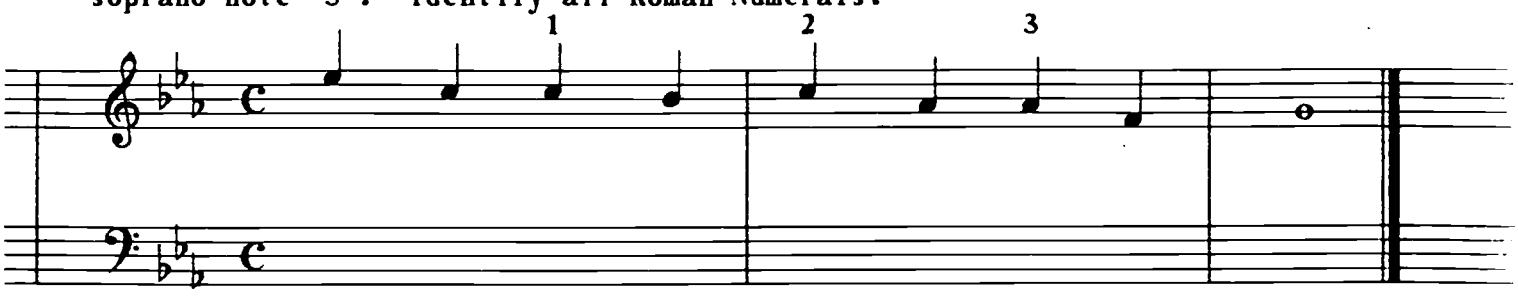
G Mi: #vi^{o7} _____ A: N^{6} I^{6}_{4} _____ G: $vii^{\emptyset 7}$ _____

II. Harmonize the following melody line (one chord per melody note) and modulate from Ab Major to F harmonic minor. Make the pivot chord supertonic in the new key. Identify all Roman Numerals:



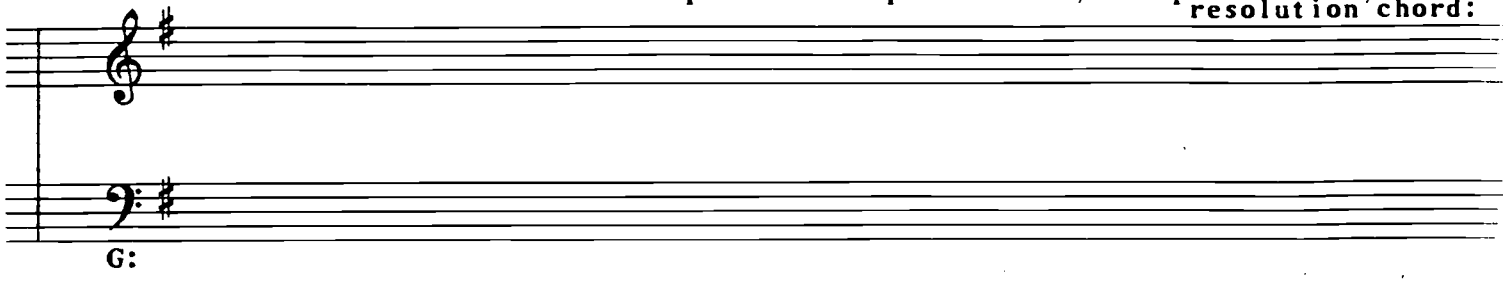
Ab:

III. Harmonize the following melody line (One chord per melody note). Include a #ii07 at soprano note "1", a secondary dominant at soprano note "2", and a borrowed chord at soprano note "3". Identify all Roman Numerals:



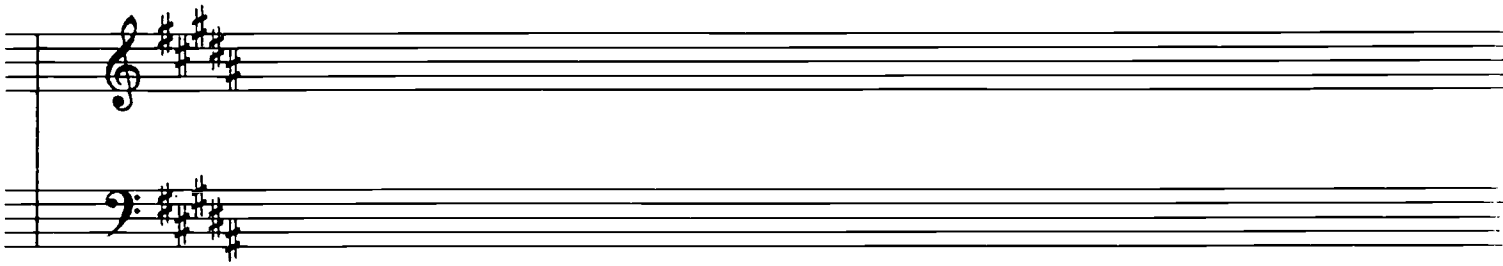
Eb:

IV. Modulate from G Major using a pivot chord which is V^7/iii in the old key and a German 6th in the new key. Name that key and spell the chord in terms of the new key. Resolve the chord and identify all Roman Numerals. You need only provide a total of three chords: A chord to precede the pivot chord, the pivot chord, and a resolution chord:



G:

V. Modulate from the key of B Major to the key of F Major using a pivot chord which is a vii07 in the old key and something else in the new key. Spell the chord in terms of the new key. Resolve the chord and identify all Roman Numerals. You need only provide a total of three chords: A chord to precede the pivot chord, the pivot chor and a resolution chord:



B:

Appendix D:

Seventh Chords/Secondary Dominants Test Instructions

TEST ON SEVENTH CHORDS AND SECONDARY DOMINANTS

INSTRUCTIONS FOR TEST:

I appreciate your taking the time to help in a study which will ultimately result in the development and implementation of a Harmony Coach designed to help students use diatonic and chromatic harmony in the context of part-writing, harmonization, and analysis .

Although you may use a pen to complete this test, you may wish to use a pencil instead. If you wish to use a pencil but did not bring one, please ask your teacher for one at this time. You should not turn the page until you are told to do so.

Please make sure that you put your name in the blank provided for it on the first page. There are two parts of the test -- one on chord construction and one on analysis. In the first part, you are to write in the notes SATB for the chord indicated and then the resolution chord, following good part-writing and doubling principles. Provide the Roman Numeral for the second chord. In the second part, you are simply to write in the appropriate Roman Numerals in the blanks provided. In both parts of the test, you should take care to use the correct case (upper or lower) and other symbols necessary for the correct chord identification.

Guessing is allowed and encouraged. However, do not take an inordinate amount of time on any question. You will need to finish the test within the amount of time allotted by your instructor. Do as well as you can on the test. Again, thank you very much for your help in this important project.

Sincerely yours,

Michael Arenson,
Associate Professor, Department of Music
University of Delaware

Appendix E:

Seventh Chords/Secondary Dominants Test Form

TEST ON SEVENTH CHORDS AND SECONDARY DOMINANTS NAME: _____

I. Construct the chords as indicated below and resolve each one. Identify the Roman Numeral for the second chord:

(a)

Bb Major: iii^7 _____

(b)

F# Minor: VI^7 (Passive Resolution) _____

(c)

Eb Major: IV^7 _____

(d)

B Minor: V^4_2/III _____

(e)

E Minor: i^7 _____

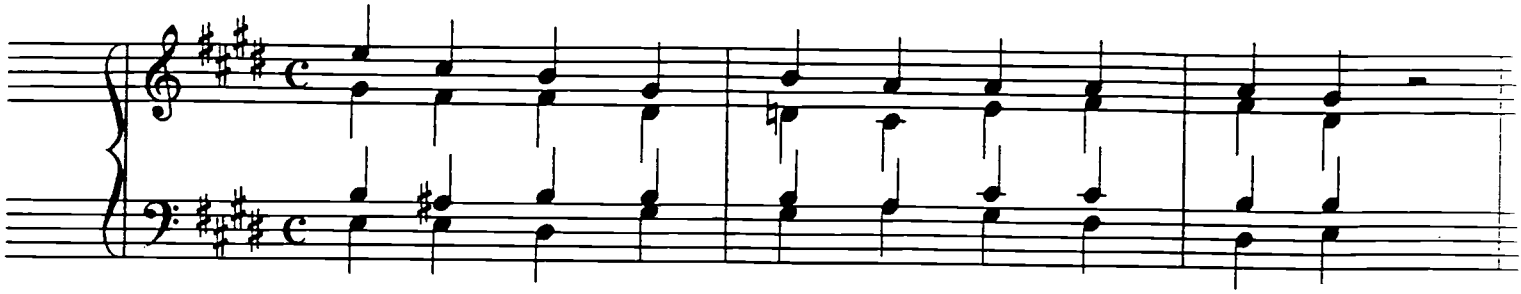
(f)

F Major: vii$^{\emptyset 7}$ _____

(g)

D Major: vii$^{07}_{65}$ /ii _____

II. In the blanks below the chords given, write in the Roman Numerals (including all inversion numbers correctly):



E Major: ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

Appendix F:
Comments to FIPSE

Evaluation Budgets

Even if the software had been ready, our budget, as proposed, would have been inadequate for a thorough evaluation. Like landscaping, when building a house, evaluation is often an afterthought. Even when there is the desire to do adequate evaluation from the beginning, the evaluation segment is often the first to be cut when trying to reduce the budget. FIPSE should work with grantees to make sure their budget is adequate for complete evaluation.

Outside Consultants

The consultancy services provided by Dr. Gary Wittlich, Indiana University, were extremely valuable to the project. It is easy to become parochial in one's approach to a problem. Bringing in outsiders to spend a day or two reviewing a project can provide a new approach to a problem and stimulate critical and creative thinking.

The FIPSE guidelines for consultants provide for a maximum fee of $300 per day. Given current market conditions, this maximum is below the normal rate for "expert" consultants. Perhaps the time has come for the maximum consultant fee to be raised.

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement (OERI)
Educational Resources Information Center (ERIC)

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